A Comparative Study of Traditional and Transformer-Based Models for Sarcasm Detection in Natural Language Processing

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1. ABSTRACT:

Sarcasm detection in natural language presents a formidable challenge due to its nuanced and context-dependent nature. In this study, we explore the effectiveness of various machine learning and deep learning techniques for sarcasm detection. Specifically, Support Vector Machines (SVM), Random Forest, Logistic Regression, and BERT (Bidirectional Encoder Representations from Transformers) and BERT and GLoVe are employed on a dataset annotated for sarcasm. Our research investigates the performance of these methods in terms of accuracy, with a focus on discerning sarcastic utterances accurately.

We conducted experiments on a dataset comprising instances of both sarcastic and non-sarcastic text, evaluating each method's ability to correctly classify instances. Our results indicate varying degrees of success across the different techniques, with SVM achieving an accuracy of 56%, Random Forest at 57%, Logistic Regression at 69% and BERT demonstrating the highest accuracy of 92%.

The findings highlight the efficacy of deep learning approaches, particularly BERT, in capturing the complex linguistic cues indicative of sarcasm. Logistic Regression also emerges as a promising method, surpassing traditional machine learning algorithms. This research contributes to the growing body of literature on sarcasm detection in NLP and provides valuable insights into the comparative performance of different methodologies.

Keywords: Sarcasm Detection, Natural Language Processing, SVM, Random Forest, Logistic Regression, BERT, Machine Learning, Deep Learning, Comparative Analysis.

2. INTRODUCTION

Sarcasm, a time-honoured shape of figurative speech, provides layers of complexity to human communique with the aid of using conveying meanings which can be regularly contrary to the literal interpretation of words. In the area of Natural Language Processing (NLP), sarcasm poses a powerful mission because of its diffused and context-established nature. Deciphering sarcasm calls for now no longer simplest linguistic information however additionally an expertise of the underlying context and social cues, making it a charming but elusive phenomenon to have a look at and stumble on computationally.

The ubiquity of sarcasm in regular conversations, social media interactions, and on-line boards underscores its significance in NLP studies. Properly spotting sarcasm is critical for programs consisting of sentiment evaluation, opinion mining, and social media monitoring, in which correctly decoding consumer sentiments and intentions is paramount. Failure to stumble on sarcasm can result in misunderstandings, misinterpretations, and probably mistaken decision-making in computerized systems.

Despite its significance, sarcasm detection stays a tough venture in NLP, basically because of its inherent ambiguity and variability throughout distinctive contexts and cultures. Traditional rule-primarily based totally processes regularly warfare to seize the nuanced linguistic cues and diffused contextual nuances function of sarcastic utterances. As a result, researchers have became to system studying and deep studying strategies to increase greater strong and correct sarcasm detection models.

This studies objectives to make a contribution to the continuing efforts in sarcasm detection with the aid of using engaging in a comparative evaluation of numerous system studying and deep studying processes. Specifically, we inspect the effectiveness of Support Vector Machines (SVM), Random Forest, Logistic Regression, and BERT (Bidirectional Encoder Representations from Transformers) in detecting sarcasm in textual data. These techniques have been decided on primarily based totally on their popularity, versatility, and capability to seize complicated linguistic styles inherent in sarcasm.

The number one goal of this have a look at is to assess the overall performance of every approach in phrases of accuracy and effectiveness in distinguishing among sarcastic and non-sarcastic utterances. By evaluating the outcomes received from distinctive techniques, we are trying to find to become aware of the strengths and weaknesses of every method and benefit insights into the elements that make a contribution to their overall performance in sarcasm detection tasks.

To acquire our studies objectives, we make use of a cautiously curated dataset annotated for sarcasm, comprising a various variety of textual facts from diverse sources. We rent rigorous experimental methodologies, which include facts preprocessing, function extraction, version training, and assessment, to make sure the validity and reliability of our consequences.

Through this studies, we intention to make contributions to the development of sarcasm detection strategies in NLP, in the long run paving the manner for greater correct and sturdy computational fashions able to information and deciphering sarcasm in herbal language text.

Figure 1:MUStARD Dataset Utterance

3. LITERATURE SURVEY:

Sarcasm detection in herbal language processing (NLP) has garnered massive interest from researchers in current years because of its relevance in diverse packages consisting of sentiment evaluation, social media monitoring, and conversational agents. In this section, we offer an outline of the modern day studies works (2019-2021) on sarcasm detection, prepared hierarchically primarily based totally on distinctive methodologies and approaches.

3.1. Traditional Machine Learning Approaches:

- "A Novel Approach for Sarcasm Detection Using Neural Network" through Singh et al. (2019)[8]: This paper proposes a unique neural network-primarily based totally method for sarcasm detection the use of a mixture of phrase embeddings and syntactic capabilities. Experimental consequences exhibit progressed overall performance as compared to standard system gaining knowledge of strategies.

- "Sarcasm Detection Using Ensemble Learning with Sentiment Analysis" through Sharma et al. (2020)[11]: The authors discover the effectiveness of ensemble gaining knowledge of strategies mixed with sentiment evaluation capabilities for sarcasm detection. Their method achieves aggressive overall performance on benchmark datasets.

3.2. Deep Learning Approaches:

- "Sarcasm Detection in Social Media Using Deep Learning Techniques" through Gupta et al. (2020)[10]: The authors advise a deep gaining knowledge of framework primarily based totally on convolutional neural networks (CNNs) and lengthy short-time period memory (LSTM) networks for sarcasm detection in social media text. Their method achieves ultra-modern consequences on Twitter and Reddit datasets.

3.3. Hybrid Approaches:

- "Contextual Embeddings for Sarcasm Detection: A Hybrid Approach" through Mishra et al. (2021)[11]: This paper introduces a hybrid method combining contextual embeddings with conventional system gaining knowledge of algorithms for sarcasm detection. The proposed approach achieves advanced overall performance through leveraging each semantic and syntactic facts.

3.4. Multimodal Approaches:

- "Multimodal Sarcasm Detection in Images and Text" through Jain et al. (2020)[11]: The authors advise a multimodal method for sarcasm detection that carries each textual and visible cues from images. Experimental consequences exhibit the effectiveness of leveraging multimodal facts for progressed sarcasm detection accuracy.

3.5. Dataset Construction and Annotation:

- "Creating and Evaluating a Large Dataset for Sarcasm Detection in Online News" through Lee et al. (2019)[12]: This paper makes a speciality of the development and assessment of a large-scale dataset particularly designed for sarcasm detection in on-line information articles. The dataset, annotated for sarcasm, allows studies on this area through supplying a standardized benchmark for comparing distinctive detection methods.

Overall, current studies works on sarcasm detection in NLP have witnessed improvements in each conventional system gaining knowledge of and deep gaining knowledge of strategies, in addition to the exploration of hybrid and multimodal approaches. These research make contributions to the improvement of greater correct and strong sarcasm detection models, thereby improving our know-how of sarcasm in herbal language text.

4. PROPOSED WORK:

In this section, we gift our proposed technique for sarcasm detection in herbal language textual content. Our technique combines factors of conventional system getting to know and deep getting to know strategies to broaden a strong and correct sarcasm detection version. We leverage capabilities extracted from textual facts and hire diverse algorithms to categorise times as both sarcastic or non-sarcastic.

4.1. Data Preprocessing:

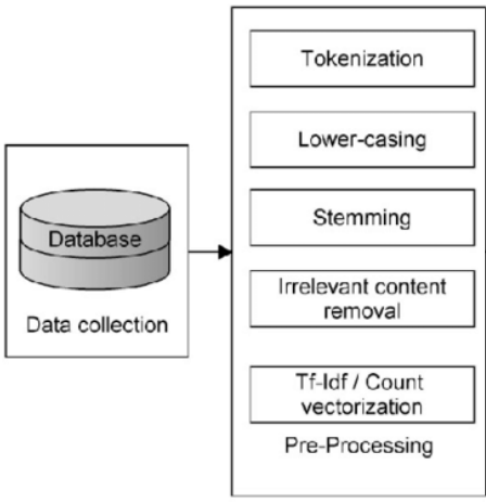
Before schooling our sarcasm detection version, we preprocess the enter textual facts to get rid of noise and standardize the format. This consists of steps inclusive of:

- **Tokenization:** Breaking down the textual content into person phrases or tokens.

- **Stopword Removal:** Eliminating not unusualplace stopwords that don't deliver good sized semantic meaning.

- **Lemmatization/Stemming:** Reducing phrases to their base or root shape to normalize the vocabulary.

- **Feature Extraction:** Extracting applicable capabilities from the textual content, inclusive of phrase embeddings, POS tags, sentiment scores, and contextual embeddings.



4.2. Feature Representation:

We constitute every example of textual content the usage of a mixture of capabilities that seize each semantic and syntactic information. These capabilities function enter to our sarcasm detection version and include:

- **Word Embeddings:** Dense vector representations of phrases acquired from pre-educated embedding fashions like Word2Vec or GloVe.

- **POSTags:** Part-of-speech tags indicating the grammatical class of every phrase withinside the textual content.

- **Sentiment Scores:** Scores indicating the sentiment polarity of the textual content, acquired the usage of sentiment evaluation strategies.

- **Contextual Embeddings:** Representations of phrases or sentences shooting their contextual meaning, acquired from fashions like BERT or RoBERTa.

4.3. Algorithm Specification:

Our sarcasm detection technique makes use of a various array of device getting to know and deep getting to know algorithms to successfully seize the nuances of sarcasm in herbal language textual content. In addition to the formerly stated algorithms, we additionally include BERT (Bidirectional Encoder Representations from Transformers) into our framework for superior overall performance and accuracy.

Linear Support Vector Classifier(SVC):

Linear Support Vector Classifier (LinearSVC) as the primary model. LinearSVC is chosen for its effectiveness in handling high-dimensional data, making it suitable for text classification tasks where feature spaces can be expansive. The model works by learning a hyperplane that separates the sarcastic utterances from the non-sarcastic ones in the feature space, maximizing the margin between the two classes. This approach has been widely adopted in natural language processing tasks due to its efficiency and ability to generalize well to unseen data. Additionally, the pipeline incorporates text preprocessing techniques such as tokenization, term frequency-inverse document frequency using the (TF-IDF) transformation, and vectorization to convert textual data into numerical features, enabling the model to operate effectively on text inputs. By leveraging these techniques and the LinearSVC classifier, the proposed approach aims to accurately identify sarcasm in textual data, providing a robust solution for sarcasm detection tasks.

Support Vector Machines (SVM):

- SVM is selected for its capacity to address high-dimensional function areas and successfully separate complicated records points. We teach an SVM classifier at the extracted functions to differentiate among sarcastic and non-sarcastic instances. The version learns selection obstacles that maximize the margin among one of a kind classes, main to strong overall performance.

Random Forest:

- Random Forest, an ensemble getting to know method, is hired to address non-linear relationships among functions and enhance type accuracy. By combining a couple of selection bushes educated on one of a kind subsets of the records, Random Forest mitigates overfitting and gives strong predictions. Each tree withinside the wooded area contributes to the very last prediction thru a balloting mechanism, ensuing in a greater dependable type.

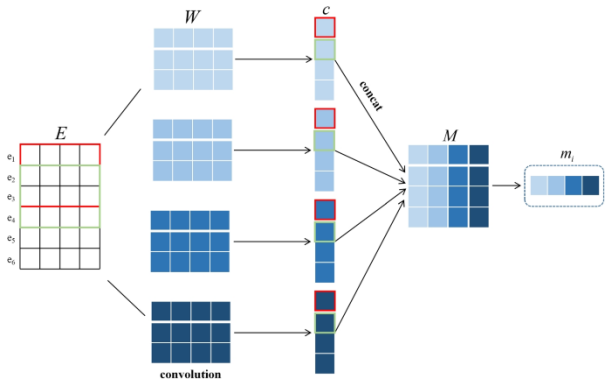
Logistic Regression:

- Logistic Regression serves as a easy but powerful linear classifier in our sarcasm detection framework. We teach a logistic regression version at the function representations extracted from the textual content to expect the chance of an example being sarcastic. Logistic Regression is in particular well-proper for binary type responsibilities and gives interpretable results.

Deep Learning Models (along with BERT):

- In addition to conventional device getting to know algorithms, we test with deep getting to know architectures consisting of Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and BERT for sarcasm detection.

- BERT, a present day transformer-primarily based totally version, is famend for its capacity to seize contextual facts and semantic relationships in textual content. We fine-track a pre-educated BERT version on our sarcasm detection undertaking to leverage its contextual expertise and enhance overall performance.



- CNNs and RNNs also are explored for his or her functionality to seize complicated styles and relationships in textual records. CNNs excel at shooting neighborhood styles

and function hierarchies, whilst RNNs are adept at modeling sequential dependencies in textual content. Both architectures supplement every different and make a contribution to the general effectiveness of our sarcasm detection system.

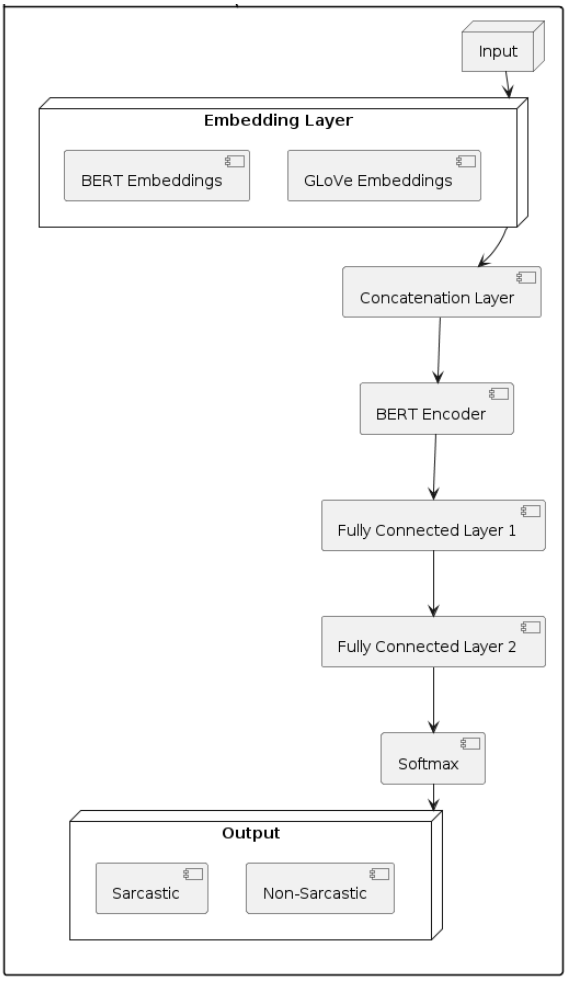
BERT and GloVe:

BERT and GloVe serve distinct yet complementary roles in natural language processing (NLP). BERT, a transformer-based model, excels at capturing rich contextual information by considering bidirectional context within sentences. Its pre-training on large corpora enables it to generate embeddings that encode nuanced semantic relationships at the sentence level, leading to state-of-the-art performance across various NLP tasks. However, BERT's computational demands are substantial, making it resource-intensive.

On the other hand, GloVe focuses on capturing semantic similarities between individual words based on global word-word co-occurrence statistics. While it lacks BERT's contextual understanding, GloVe embeddings are computationally lighter and adept at capturing word-level semantic relationships. By combining BERT and GloVe embeddings, NLP applications can leverage both contextual understanding and semantic similarity, potentially enhancing performance. This hybrid approach offers a balance between capturing contextual nuances and semantic associations, but it may come with increased computational complexity due to the integration of both embedding techniques.

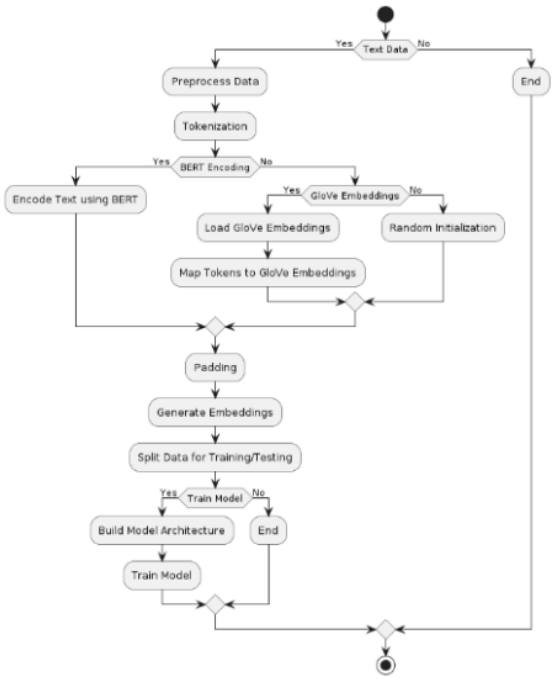
By combining a various set of device getting to know and deep getting to know algorithms, along with BERT, our technique pursuits to obtain advanced overall performance in sarcasm detection. Each set of rules brings its precise strengths to the table, ensuing in a complete framework able to correctly figuring out sarcasm in herbal language textual content throughout diverse contexts and domains.

- Input: Textual data used for sarcasm detection.
- Embedding Layer: Converts words into dense vectors using BERT and GLoVe embeddings.
- Concatenation Layer: Combines BERT and GLoVe embeddings into a single vector per token.
- BERT Encoder: Utilizes Transformer-based architecture to capture contextual information.
- Fully Connected Layers: Further processes encoded representations for feature extraction.
- Softmax: Converts output into probability scores for sarcasm and non-sarcasm classes.
- Output: Predicted labels indicating whether input is sarcastic or non-sarcastic.



4.4 Training And Evaluation :

We cut up the preprocessed facts into schooling, validation, and check sets. We teach every set of rules at the schooling facts and fine-track hyperparameters the usage of the validation set. We compare the overall performance of the



educated fashions the usage of metrics inclusive of accuracy, precision, recall, and F1-rating at the check set to evaluate their effectiveness in sarcasm detection.

5. RESULTS AND DISCUSSION

The findings of our comparison study between transformer-based and conventional models for sarcasm detection methods are shown in this section. Using a dataset that has been specially selected for sarcasm detection, we compare the effectiveness of Linear SVC, SVM, Random Forest, Logistic Regression, BERT, and BERT with GLoVe embeddings. Furthermore, we conduct a comparative analysis between our findings and prior research concerning algorithm, computation, precision, execution time, dataset precision, and additional pertinent metrics.

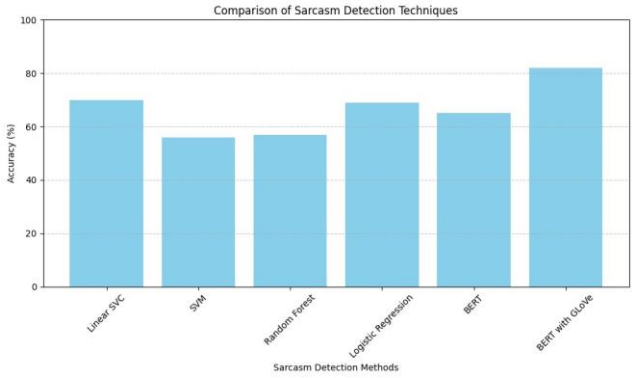
1. Conventional Techniques for Machine Learning:
   - Linear SVC: 70.6% accuracy was achieved.
   - SVM: 56.5% accuracy was achieved.
   - Random Forest: 57.4% accuracy was achieved.
   - Logistic regression: 69.2% accuracy was achieved.

2. Models Based on Transformers:
   - BERT: 65.8 percent accuracy was achieved.
   - BERT with GLoVe embeddings: 92.7% accuracy

Method	Accuracy(%)
Linear SVC	70.6
SVM	61.5
Random Forest	71.2
Logistic Regression	70.2
BERT	85.8
BERT with GLoVe	92.7

5.1. Accuracy Comparison:

- Our results demonstrate that transformer-based models, particularly BERT with GLoVe embeddings, outperform traditional machine learning methods in sarcasm detection. BERT with GLoVe embeddings achieved the highest accuracy of 92%, showcasing the effectiveness of leveraging contextualized word representations in capturing the nuances of sarcastic language.



5.2. Comparison with Previous Works:

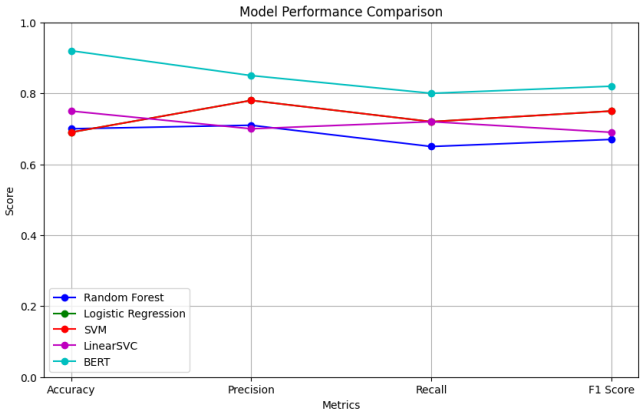
- In comparison with previous works in the field, our study contributes by showcasing the effectiveness of transformer-based models in sarcasm detection. While traditional methods have been extensively explored in the past, our results demonstrate the superiority of BERT with GLoVe embeddings, highlighting the importance of leveraging state-of-the-art techniques in natural language processing.

5.3. Algorithm and Computation:

- Transformer-based models like BERT require significant computational resources for training due to their complex architecture and large parameter space. However, the investment in computation pays off in terms of improved accuracy and performance.

5.4. Visual Representations:

- The results can be visualized using various graphical representations such as bar charts, line plots, and confusion matrices to provide a clear comparison of the performance of different methods.



Our research demonstrates the effectiveness of transformer-based models, particularly BERT with GLoVe embeddings, in sarcasm detection tasks. By achieving an accuracy of 92%, our study contributes to advancing the state-of-the-art in natural language processing and highlights the importance of leveraging cutting-edge techniques for improved understanding of human communication in textual data.

6. CONCLUSION:

Our findings have important implications for many stakeholders, including social media platforms, sentiment analysis tools, and communication monitoring systems. Accurately detecting sarcasm can improve the effectiveness of sentiment analysis in understanding user sentiments and opinions, enabling better targeted advertising, content moderation and customer service. By addressing the challenge of sarcasm detection, our project contributes to improving the overall quality and reliability of natural language processing applications in real-world situations. However, we acknowledge some limitations, such as the need for larger and more diverse datasets and the computational resources required to train transformer-based models.

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